

ANALYSIS OF WIGNER ENERGY IN BGRR GRAPHITE

(FINAL ANALYSIS)

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November 2006

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Analysis of Wigner Energy in BGRR Graphite

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Eight segments (4" long slugs) of cores were obtained from BGRR for analysis of Wigner Energy retained in the graphite. Graphite was scraped from each end of each slug giving two samples from each specimen. Between 10 and 20 mg of this graphite powder were weighed into platinum analysis cells and subjected to thermal analysis on a Shimadzu Differential Scanning Calorimeter (DSC-50). The samples were annealed in nitrogen up to 700 ° C at a scan rate of 20° C/minute with data recorded at one second intervals. Each sample was run twice; the first scan provided the energy profile of the "as received" material and the second scan provided the background energy profile of the specimen, as the Wigner Energy had been removed during the first annealing. An example is shown in Figure 1. The blank was subtracted from the initial scan to give the Wigner energy profile. The appendix contains two graphs for each sample. One graph presents the data in J/s/g and shows the results of the two scans described above; the energy measurement of the 'as received' and the same sample after annealing. The other graph presents the data in J/g/K, which was calculated by subtracting the background scan data from the first scan and dividing by the heating rate. The heating rate was nominally 20 K /minute (0.333K/s), however regression analysis provided a more accurate heating rate of 0.3506 K/s and this was used to determine J/g/K. These values were plotted against temperature in C. From these plots the temperature at which energy release increases can be determined. The data (J/s/g) were summed providing a measure of total Wigner energy in the sample in Joules per gram.

The DSC analysis gives energy content of the graphite that ranges from around 0 (actual measurements of samples from Loc 4 slug 3 were -2.9 and -21.2 J/g) to 212 J/g. Table 1 gives the location and the total energy content of each sample. Figure 2 contains background subtracted scans showing two groups of peak energy release rates. The group with the greatest release rates peaks between 250 and 260°C. These samples, with the greatest amount of stored energy, reached their maximum release rate within about 100° C of the start of release; peaking at about 1 J/g/K at analysis temperatures of 255°C. The other group had much slower approaches to their maximum release rates and only reached it between 300 and 350°C. Almost

all samples began to show energy release at about 150°C. Below this temperature very little if any energy was released. A sample of reactor graphite that had not been irradiated had a similar temperature profile to the background (annealed) samples (not shown).

Comparing four samples that show high energy deposition in Figure 3, the temperature at the initial release of energy is similar (about 150°C) and the peak heights for maximum energy release are also similar. There are differences in total energy release (e.g. 13A slugs 9a and b are 211 and 123 J/g respectively) which is the result of higher energy in the later portion of the scan; from about 300° C to 700° C.

The samples taken from Location 4 slug number 3 show no Wigner energy. The initial scan and the subsequent blank scan are essentially identical, with energy deposition of -2.9 and -21.2 J/g.

Table 2 shows the total energy measured in four background subtracted replicates of the sample from Location 13A slug 19a. The mean of the four replicates was 101 J/g with a standard deviation of 30. These scans are also shown in Figure 4 where they are compared to one of the high energy scans.

Table 1. Stored Energy in BGRR Graphite Samples

Sample Location	Layer Number	Slug Number	Distance from Pile west side (Inches)	Distance from Pile center line (ft)	Graphite Type	Total Energy (J/g)
Loc 13A	37	34 a and b	132-136	(South)3.5	A	88.0, 45.7
Loc 13A	37	11 a and b	40-44	(South)3.5	D	204, 209
Loc 13A	37	49 a and b	192-196	(South)3.5	A	65.0, 145
Loc 13 A	37	19 a and b	72-76	(South)3.5	B	147, 70.7
Loc 13 A	37	16 a and b	60-64	(South)3.5	B	177, 113
Loc 13 A	37	9 a and b	32-36	(South)3.5	D	211, 123
Loc 3 (I-5)	65	33 a and b	128-132	(South)6.0	C	105, 49.0
Loc 4	65	3 a and b	8-12	(South)10.5	D	-21.2, -2.9

Table 2. Total Energy of 4 replicates

Sample	Total energy J/g
13-19a #1	145
13-19a #2	98.3
13-19a #3	78.4
13-19a #4	83.6
mean (std dev)	101 (30.3)

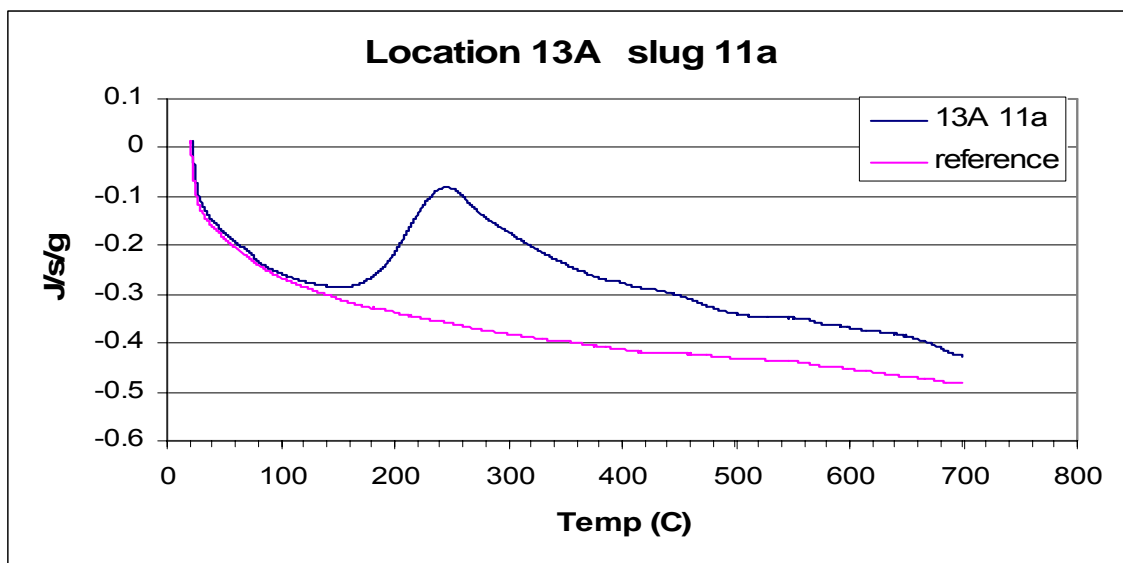


Figure 1. A pair of DSC scans showing the release of energy from the first scan and then the same sample rescanned after the energy had been released. Each sample was run twice to provide a blank which ascertained that the energy observed in the first scan was Wigner energy.

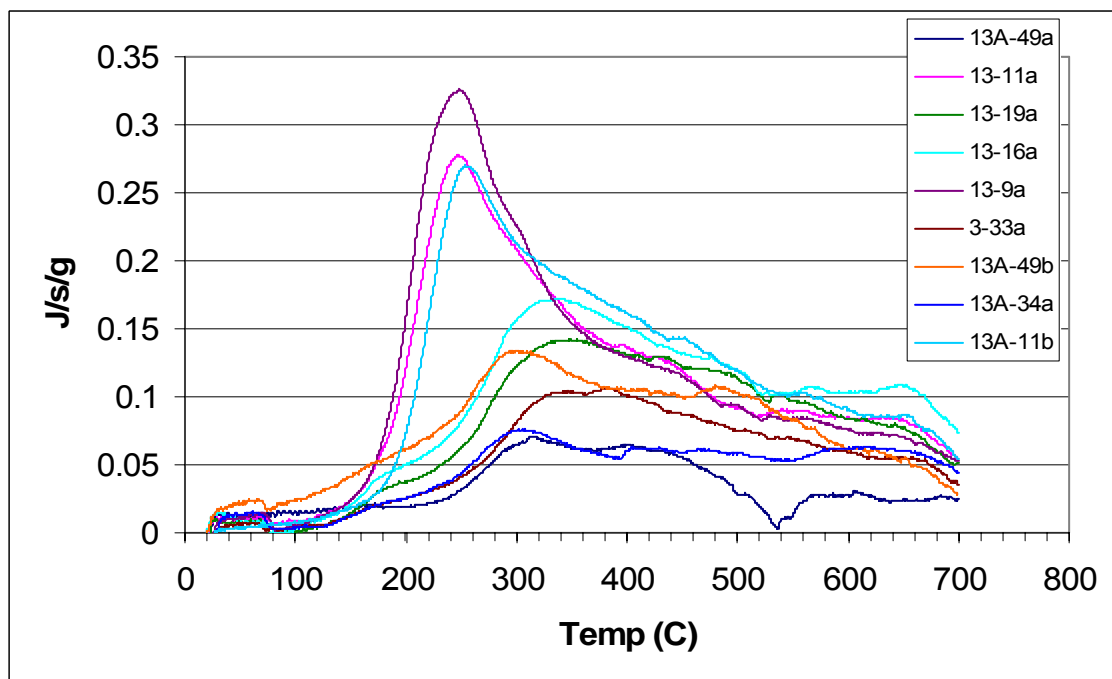


Figure 2. Background subtracted DSC scans of graphite samples from the BGRR interior. Summing the energy in each interval (1 second) gives area under the peak and a measure of total energy released.

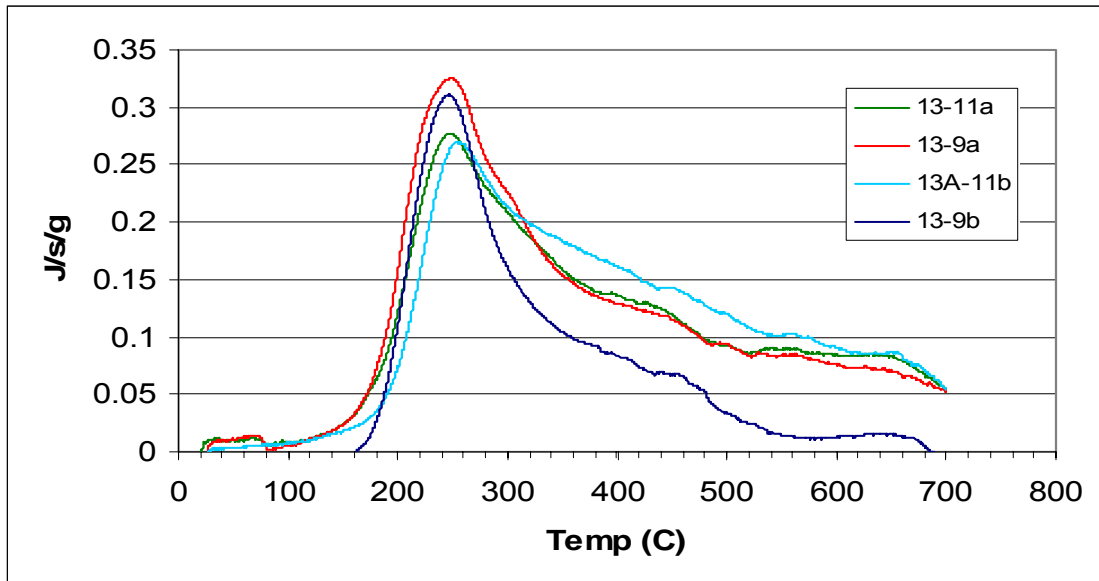


Figure 3. Background subtracted comparison of higher energy samples. Differences in total energy are primarily caused by different profiles in the latter portion of the scans.

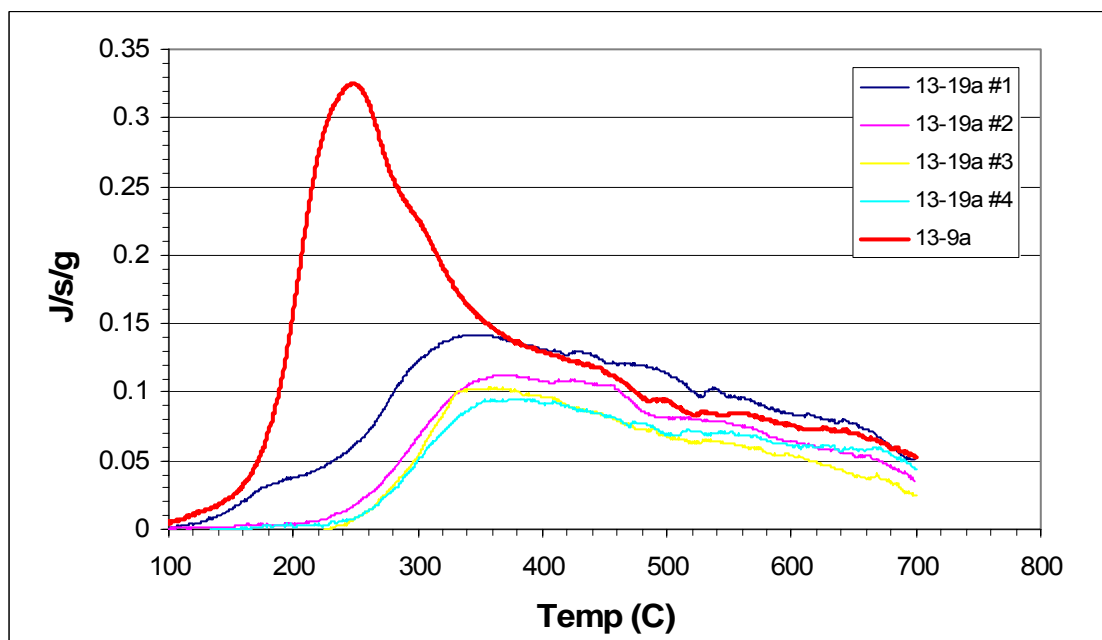


Figure 4. Four replicates of the sample from Location 13A slug 19a and a scan of a high energy sample for comparison.

APPENDIX 1

DSC Scans of BGRR Graphite

